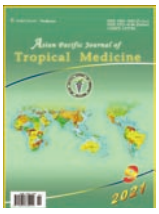

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Foodborne parasitic diseases in China: A scoping review on current situation, epidemiological trends, prevention and control

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ABSTRACT

Objective: Foodborne parasitic diseases, although with a declining overall incidence rate, are still endangering local public safety. This review aims to describe the current situation and epidemiological trends of foodborne parasitic diseases in China in order to explore possible reasons contributors to its high prevalence in some areas, and propose strategies for prevention and control accordingly.

Methods: A scoping review was conducted by searching PubMed, CNKI, Wanfang, CQVIP, Embase, and the Cochrane Library using search formula "foodborne parasitic diseases (or foodborne parasites)" AND "China". Studies on foodborne parasitic diseases in China were considered, but only articles in English or Chinese published between January 1980 and June 2020 were retrieved. Included studies were screened according to the eligibility criteria: 1) diseases consistent with the WHO definition of foodborne parasitic diseases; 2) the food carriers were included in the WHO food classification; 3) data related to epidemiology, pathogenicity, and prevention and control; 4) Foodborne parasitic diseases cases or outbreaks in China.

Results: A total of 111 out of 665 records were included and summarized. The prevalence of clonorchiasis, angiostrongyliasis, echinococcosis, trichinellosis and cysticercosis was still increasing although the infection rate of soil-transmitted nematodes has substantially decreased in recent years. Diverse eating habits, close contact with animals, and urbanization were contributing factors to the increase.

Conclusions: Foodborne parasitic diseases remain an important public health issue in China with the progress of economic globalization and food diversification. We should manage to raise public awareness about the prevention and control of foodborne parasitic diseases, improve health and safety inspections, as well as public health practice.

KEYWORDS: Foodborne diseases; Parasitic diseases; China; Preventive medicine

1. Introduction

Foodborne parasitic diseases are acquired through the ingestion of food or drinking water contaminated with the infective stage of parasites. The diseases present some unique challenges and are often referred to as neglected diseases, which might result in major public health and socioeconomic problems[1]. The World Health Organization (WHO) found in 2006 that 7% of foodborne diseases in the world are caused by parasites[2]; meanwhile, in

Significance

Foodborne parasitic diseases are transmitted by contaminated food. This article comprehensively reviews and summerizes the clinical and epidemic characteristics of foodborne parasitic diseases in China. This review amis to provide information to health care administrators and clinicians for a better control and prevention of parasitic diseases.

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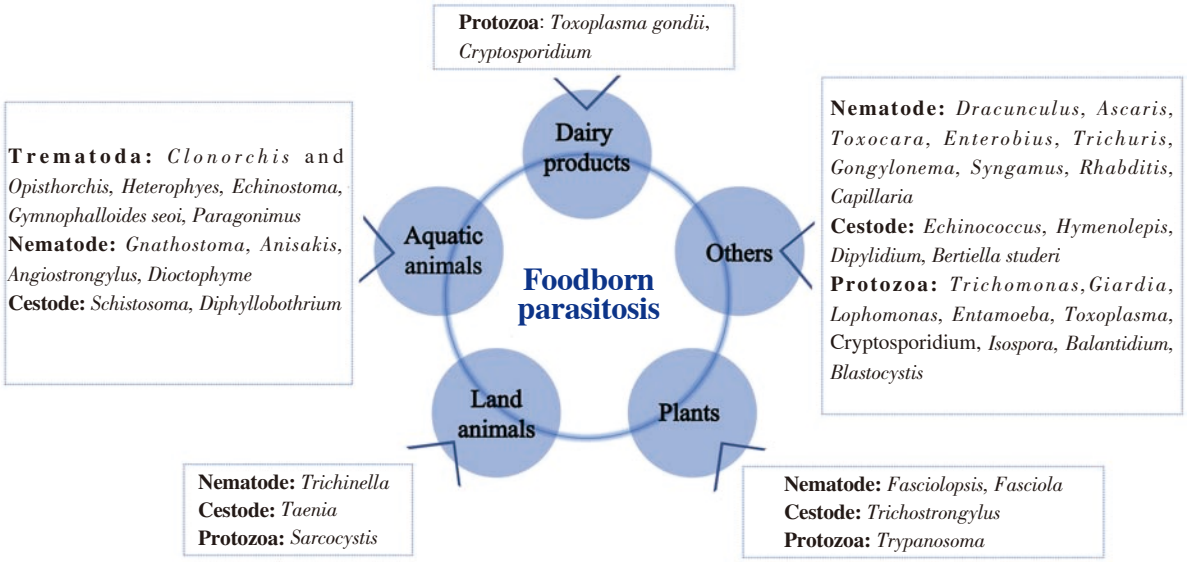

Figure 1. Five food categories and related foodborne parasitic diseases.

China, approximately 150 million people were reported to suffer from foodborne parasitic zoonoses in 2005 and more people were at risk[3]. Transmission and prevalence are mainly associated with human behavior patterns of preparing food and dietary habits. The populations in endemic areas usually have formed related dietary traditions and customs of eating raw or undercooked food[4]. However, their habits and traditions are difficult to change. In addition, the life cycles of parasites might be extremely complicated, which may include multiple intermediate hosts and definite hosts, and some of them may become food. In addition, the parasites themselves might contaminate food or water. The WHO classifies food causing foodborne parasitic diseases into five categories: land animals (*i.e.*, beef, pork and poultry), aquatic animals (*i.e.*, marine fish, freshwater fish, shellfish and aquatic mammals), dairy products, plants (*i.e.*, berries, fruits, leafy greens and vegetables) and others (*i.e.*, snakes, frogs and insects) (Figure 1)[5]. To date, a ninety-three foodborne parasites have been identified, and some of them may lead to severe illness and even death[5]. In this paper, the classification, prevalence and prevention and control strategies for foodborne parasitic diseases are reviewed to provide new insights for better control of foodborne parasitic diseases in China.

2. Materials and methods

2.1. Search strategy

We searched the term "foodborne parasitic diseases (or foodborne parasites)" AND "China" in three English and three Chinese electronic databases, including PubMed (https://www.ncbi.nlm.nih.gov/pubmed/), Embase (www.embase.com/), Cochrane Library (www.cochranelibrary.com/), CNKI (www.cnki.net), Wanfang (www.wanfangdata.con.cn) and CQVIP (http://www.cqvip.com/). After reading the title/abstract or the full article if necessary, we summarized the current situation, epidemiological trend and its characteristics, and the prevention and control of foodborne parasitic diseases in China. Then, we searched every genus we found in the first step (such as *Clonorchis*, *Opisthorchis*, *etc.*) AND epidemiology (or infection or pathogenicity) AND China. Finally, we searched every genus we mentioned (such as *Anisakis*, *Gongylonema*, *etc.*) AND case report (or misdiagnosis) from 1980 to 2020 in China. Manual searching was not performed, and the gray literature was not searched neither.

2.2. Eligibility criteria

Papers were included if they fulfilled the following criteria: 1) consistent with the WHO definition of foodborne parasitic diseases; 2) the food carriers were included in the WHO food classification; 3) presented information related to epidemiology, pathogenicity, and prevention and control; 4) written in English or Chinese; 5) published during January 1, 1980, to June 10, 2020; and 6) the case or outbreak occurred in China.

2.3. Data extraction, summary and data charting process

We extracted information from the included studies under the following categories: 1) the classification, prevalence and pathogenicity of foodborne parasitic diseases; 2) the epidemiological

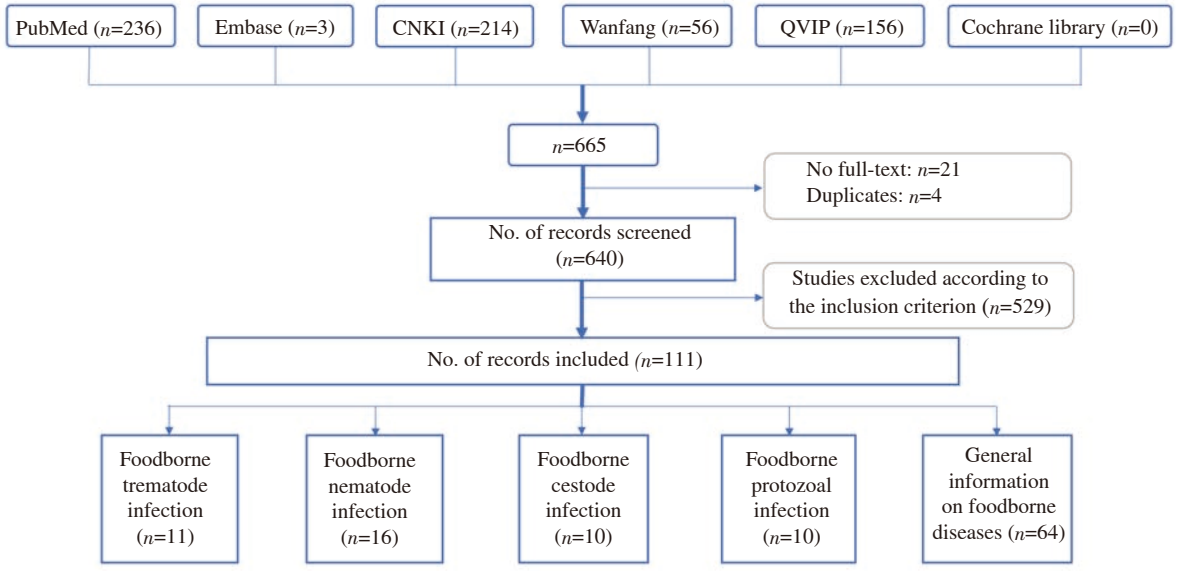

Figure 2. PRISMA flow diagram showing the scoping review process.

trends and characteristics of foodborne parasitic diseases; and 3) the prevention and control strategies for foodborne parasitic diseases. Two authors independently assessed eligibility, extracted data and cross-check results with disagreements resolved by consensus.

3. Results

3.1. Search findings

Six hundred sixty-five records were retrieved. After excluding 21 records due to lack of full text, 4 records due to duplication, and 529 records that met the exclusion criteria mentioned above, 111 records were eventually included in this review. Figure 2 presents a flowchart of the selection process.

3.2. The classification, prevalence and pathogenicity of foodborne parasitic diseases in China

The foodborne parasitic diseases that have been identified or posed a potential threat in China are summarized and listed in Table 1-4. The pathogens are divided based on the biological classification of parasites (trematodes, nematodes, cestodes and protozoa) and are further classified according to the five major food sources mentioned above. Under each classification, the distribution, parasitic site and pathogenicity are recorded. Among them, foodborne trematode and cestode infections are numerous, widely distributed, closely related to diseases, and diverse in pathogenicity, thus attracting the most widespread attention. However, relatively few epidemiological investigations have been conducted on foodborne nematode and protozoan diseases in China.

Regarding the epidemiological distribution, information on the spatial distribution is relatively complete. However, few studies have examined the temporal and population distributions. For the study of pathogenicity, the location of the parasite and the possible symptoms and signs or pathological changes have been clearly documented, but few studies have investigated the specific pathogenic mechanism.

3.2.1. Foodborne trematode infections

Foodborne trematode diseases are mainly transmitted by the consumption of raw or undercooked food such as fish, crustaceans and vegetables that harbor the larval stages of the parasites[6]. A national survey conducted in 2005 showed that human clonorchiasis is endemic in 27 provinces, with the largest number of infected people (~5.5 million) in Guangdong; human paragonimiasis is prevalent in 24 provinces, with the highest prevalence in Shanghai (5.1%) and Chongqing (4.1%), respectively. Fasciolopsiasis was formerly one of the most dominant trematodes, as revealed by the first national survey between 1988 and 1992, and was distributed across 16 provinces with 9 531 infections; 148 people were infected with *Fasciola* (*F.*) *hepatica*, and 9 people were infected with *F. gigantica*[7]. The types, distribution and pathogenicity of common foodborne trematode infections in China are listed in Table 1, which includes trematodes carried by aquatic animals such as *Clonorchis* and *Opisthorchis*[8,9], *Heterophyes*[10], *Echinostoma*[11], *Gymnophalloides seoi* and *Paragonimus*[12–14], and trematodes carried by plants such as *Fasciolopsis* and *Fasciola*[15,16].

Table 1. Types, distribution and pathogenicity of foodborne trematode infections in China.

Food category	Genera	Food vehicles	Distribution			Parasitic sites	Pathogenicity	Ref.
			Temporal	Spatial	Population			
Aquatic animals	*Clonorchis* and *Opisthorchis*	Undercooked freshwater fish containing larvae	Spread throughout the year	Guangdong, Guangxi, Heilongjiang, *etc.*	Those accustomed to eating raw fish and shrimp	Liver, gallbladder and bile ducts	Asymptomatic; typical symptoms: fever and biliary colic; severe symptoms: cholangitis, cancer, abdominal pain and nausea	[8,9]
	Heterophyes	Undercooked freshwater fish and frogs	N/A	Guangdong, Hainan, Anhui, *etc.*	Those accustomed to eating raw fish and frogs	Adults: small intestine with ectopic parasites; eggs: the whole body	Asymptomatic; typical symptoms: digestive disorders; ectopic parasites and egg deposits: depending on the site	[10]
	Echinostoma, Gymnophalloides seoi	Freshwater fish, frogs, snails, clams and *Crassostrea gigas* containing encysted metacercaria	N/A	The former: Hunan, Guangdong, Xinjiang, *et al.* The latter: N/A	Those accustomed to eating raw freshwater fish, frogs, snails and *Crassostrea gigas*	Upper small intestine, sometimes the gallbladder and pancreatic duct	Asymptomatic; typical symptoms: digestive disorders; severe symptoms: anemia, weight loss, perforation of the bowel and even death	[11,12]
	Paragonimus	Raw or pickled crustaceans	N/A	Nationwide	Those accustomed to eating raw crustaceans	Lungs, with larval migrants to the whole body	Asymptomatic; typical symptoms: cough and hemoptysis with fever and chest pain; severe symptoms: dyspnea; larval migrants: depending on the site	[13,14]
Plants	*Fasciolopsis*	Raw aquatic plants	Summer and Autumn	Zhejiang, Fujian, Guangdong, *etc.*	All ages, especially in young people	Upper small intestine, occasionally the biliary tract	Asymptomatic; typical symptoms: digestive disorders; severe symptoms: intestinal obstruction or even death	[15]
	Fasciola	Raw aquatic plants or untreated water	Sudden changes in climatic conditions	Gansu, *et al.*	Generally, susceptible	Bile duct and liver	Early phase: digestive disorders and fever; chronic phase: cholangitis, cholecystitis, and pancreatitis	[16]

3.2.2. Foodborne nematode infections

Human parasitic nematodes are widely distributed in nature and are found in water and soil. Most of them are free-living, but a small proportion parasitize the human body and cause disease[17]. Although comprehensive data on the prevalence of foodborne nematodes in China are still lacking, we can retrieve information on some common nematodes separately. Human trichinellosis is serious in several provinces, such as Yunnan and Inner Mongolia, where it has a mean prevalence of 8.3% and 6.3%, respectively in 2005[7]. Approximately 400 cases of human angiostrongyliasis have been reported in China[7]. The types, distribution and pathogenicity of common foodborne nematode infections in China are listed in Table 2, which includes nematodes transferred by aquatic animals such as *Gnathostoma*[18], *Anisakis*[19], *Angiostrongylus*[20,21], and *Dioctophyme*[22]; nematodes transferred by land animals such as *Trichinella*[23]; nematodes transferred by plants such as *Trichostrongylus*[24]; and nematodes transferred by other contaminated food or water such as *Dracunculus*[25], *Ascaris*[26], *Toxocara*[27], *Enterobius*[28], *Gongylonema*[29], *Trichuris*[30], *Capillaria*[31], *Syngamus* and *Rhabditis*[17,32].

3.2.3. Foodborne cestode infections

Most cestode adults live in the digestive tract of vertebrates, and their larvae can migrate throughout the body, resulting in visceral and cutaneous larval migrants[17]. Cysticercosis is one of the most serious foodborne parasitic diseases, and people might acquire an infection by eating food or drinking water contaminated with the eggs of *Taenia (T.) solium* or self-infection caused by eggs entering the stomach with vomiting. It was reported in 29 provinces of China with ~550 thousand infections according to a national survey conducted in 2005[7]. Echinococcosis is another important parasitic disease that is now becoming the key parasitic disease in China, with 380 thousand infections, and ~50 million individuals are at risk of infection based on a report published in 2005. In addition, ~1 000 cases of human sparganosis were reported in 22 provinces due to the ingestion of raw frogs or snakes or drinking water contamininated with eggs in 2006[7]. The types, distribution and pathogenicity of common foodborne cestode infections in China are listed in Table 3, which includes cestodes transferred by aquatic animals such as *Spirometra* and *Diphyllobothrium*[33,34]; cestodes transferred by land animals such as *Taenia*[35–37]; and cestodes transferred by other contaminated food or water such

Table 2. Types, distribution and pathogenicity of foodborne nematode infections in China.

Food category	Genera	Food vehicles	Distribution			Parasitic sites	Pathogenicity	Ref.
			Temporal	Spatial	Population			
Aquatic animals	G*nathostoma*, *Angiostrongylus*	Raw freshwater fish, snails, frogs, vegetables, pigs and chickens	N/A	Nationwide, Taiwan, Hong Kong, Guangdong	Those accustomed to eating raw fish, snails and meat	Larval migrants	Depending on the site, such as lame rash, migrating subcutaneous mass and eosinophilic encephalomyelitis	[18,21]
	Anisakis	Raw marine fish	N/A	N/A	Those accustomed to eating raw marine fish	Digestive tract with larval migrants	typical symptoms: digestive disorders; severe symptoms: abdominal pain, nausea, vomiting, and mass formation	[19]
	Dioctophyme	Raw frogs, fish, or oligochaetes in untreated water	N/A	Hubei, Guangdong, Jiangsu, *etc.*	Those accustomed to eating raw frogs and fish, or drinking untreated water	Renal pelvis, sometimes the abdominal cavity, bladder and ovary	Low back pain, renal colic, repeated hematuria, frequent micturition, may be complicated by pyelonephritis, kidney stones, renal dysfunction, and acute uremia symptoms	[22]
Land animals	*Trichinella*	Raw meat, mostly pork	More in winter	Yunnan, Tibet, Sichuan.	Those eating raw pork and meat products	Small intestine with larvae migrants	Typical symptoms: digestive disorder; atypical symptoms: muscle pain, fever, facial edema, myocarditis, dysphagia and speech disorders	[23]
Plants	*Trichostrongylus*	Raw vegetables and grass leaves, untreated water	N/A	Areas where livestock are raised	Those accustomed to eating raw vegetables and drinking untreated water	Stomach, small intestine	Abdominal pain, severe anemia and toxicity caused by worm metabolites	[24]
Other	*Dracunculus*	Contaminated food or water	May to September	N/A	Aged 14-40 years	Subcutaneous tissue	Hives, local masses with systemic symptoms such as diarrhea, fever, dizziness and nausea	[25]
	Ascaris	Contaminated food or water	N/A	Yunnan, Guizhou, Jiangxi, *etc.*	Preschool-age and young children residing in rural areas	Small intestine with larvae migrants	Larvae: asthma and pneumonia, adult worms: malnutrition, hypersensitivity reactions and complications	[26]
	Toxocara	Contaminated food or water	N/A	Hot, humid and poor areas	Children and adolescents under 20 years of age; cat and dog owners	The whole body, including the liver, heart, lungs, brain, muscles or eyes	Mostly asymptomatic; larvae could cause visceral toxoplasmosis and ocular toxoplasmosis, leading to fever, cough, liver inflammation and eye problems	[27]
	Enterobius, *Trichuris*	Contaminated food or water	N/A	The southern region, Fujian, Hainan, Guangdong, *etc.*	All ages, especially children aged 5-7 years residing in areas with poor sanitation	The cecum, colon and lower ileum, with ectopic damage	Asymptomatic; typical symptoms: digestive disorder, malnutrition and itching; severe symptoms: gastrointestinal bleeding, appendicitis, intussusception and mental diseases	[28,30]
	Gongylonema	Insects	N/A	North of the Yangtze River	Young adults engaged in agriculture and domestic work	Mouth and esophagus	Typical symptoms: itching and tingling; severe symptoms: blisters or blood vesicles in local mucous membranes and mental symptoms	[29]
	Syngamus	Contaminated food or water, raw liver, gall and blood of the turtle	N/A	N/A	Those accustomed to eating raw vegetables, animal product and water	Throat, trachea, and bronchi with larvae migrants	Fever, cough, asthma, and hemoptysis	[32]
	Rhabditis	Contaminated food or water	N/A	Hubei, Hunan, Guizhou, *etc.*	Those exposed to sewage and corruption plants	Digestive and urinary systems	Asymptomatic; typical symptoms: digestive disorders and symptoms of urinary system infection	[17]
	Capillaria	Contaminated food or water	N/A	Guangdong, Henan, Fujian	Those residing in areas with poor sanitation	Liver	Typical symptoms: fever, hepatosplenomegaly; severe symptoms: lethargy, dehydration and even death	[31]

Table 3. Types, distribution and pathogenicity of foodborne cestode infections in China.

Food category	Genera	Food vehicles	Distribution			Parasitic sites	Pathogenicity	Ref.
			Temporal	Spatial	Population			
Aquatic animals	*Spirometra*	Cyclops, salamander or raw frog	N/A	Shanghai, Guangdong, Taiwan, *etc.*	Aged 10 to 30 years, with a male to female ratio of 2:1	Eye, subcutaneous tissue, maxillofacial tissue, brain, *etc.*	Migratory subcutaneous nodules, swelling, abscesses, and conjunctivitis	[33]
	Diphyllobothrium	Raw fish	N/A	Heilongjiang, Taiwan, *et al.*	Eskimos	Small intestine	Asymptomatic; typical symptoms: fatigue, diarrhea and hunger; Severe symptoms: anemia, intestinal obstruction, and gallbladder disease	[34]
Land animals	*Taenia*	Raw pork or pork liver, and raw beef, sometimes wild animals	N/A	Mostly rural areas, Heilongjiang, Jilin, Shandong, *etc.*	Mainly males and young adults	Adults: small intestine	Asymptomatic; typical symptoms: digestive disorders and intestinal obstruction;	[35–37]
Other	*Taeni solium cysticercus*	Food or water contaminated with the eggs of *Taenia solium*, or self-infection caused by the eggs entering the stomach with vomiting	N/A	Mostly rural areas, Heilongjiang, Jilin, Shandong, *etc.*	Mainly males and young adults	The whole body, mostly the brain	Depending on the number of cysticercus and the parasitic sites.	[35]
	Echinococcus	Food or water contaminated with eggs	N/A	Xinjiang, Qinghai, Gansu, *et al.*	Preschoolers, Farmers and herders	Liver, sometimes the whole body	Liver failure and hepatic encephalopathy; liver cirrhosis and portal hypertension; allergic reactions	[38,39]
	Hymenolepis, Dipylidium, and Bertiella studeri	Insects, *Tribolium castaneum*-infected fleas, infected ants and *Galumna* spp. or other food and water contaminated with eggs or cysticerci	N/A	Jiangsu, Hubei, Guangxi, *et al.*	Children aged less than 10 years residing in areas with poor sanitation, owners of cats and dogs	Small intestine	Asymptomatic; typical symptoms: neurological and digestive symptoms; severe symptoms: anemia, leukocytosis, irritability, dizziness, sluggishness and cachexia	[40–42]

as *Echinococcus*[38,39], *Hymenolepis*[40], *Dipylidium*[41] and *Bertiella studeri*[42].

Although we included *Taenia* in the category of land animals, we should always remember that cysticercosis is acquired by eating food contaminated with eggs of *T. solium*[35], and thus we listed it separately in Table 3. Additionally, in rare cases, humans can be accidentally infected with *T. taeniaeformis* and *T. hydatigena* by inadvertently eating their eggs and infected with *Mesocestoides lineatus* by ingesting the muscles or organs of animals such as frogs and snakes that contain tetrathyridium[17].

3.2.4. Foodborne protozoal infections

Approximately forty protozoan species are able to infect humans. Due to the lack of effective vaccines and difficulties in vector control, many protozoal infections are still a global public health problem[17]. Human infection with *Giardia lamblia* and *Toxoplasma gondii* has been documented in every mainland province of China. The mean infection rate of the latter is 7.9% nationwide. Human cases of cryptosporidiosis have been recorded in 14 provinces, and according to a survey conducted in Zhejiang Province in 2000, *Cryptosporidium* oocysts were detected in 57 of 548 children with diarrhea (10.4%)[7]. The types, distribution and pathogenicity of foodborne protozoan infections in China are listed in Table 4, which includes protozoa carried by land animals such as *Sarcocystis*[43], protozoa carried by plants such as *Trypanosoma*[44], and protozoa carried by other contaminated food or water such as *Trichomonas hominis*[45], *Giardia*[46], *Lophomonas*[17], *Entamoeba histolytica*, *Entamoeba coli*[47], *Toxoplasma*[48], *Cryptosporidium*[49], *Isospora belli*[50], *Balantidium* and *Blastocystis*[51,52].

3.2.5. Prevention and control strategies

Studeis on typical cases of common foodborne parasitic diseases reported in China and their diagnosis and treatment are listed in Table 5[68-110], which helps us learn lessons and propose better control strategies.

4. Discussion

4.1. The epidemiological trends and characteristics of foodborne parasitic diseases in China

From 1980 to the present, China conducted three national surveys on the distribution of human parasites ranging from 1988-1992, 2001-2004, and, most recently, 2014-2016. In the three surveys, the total infection rates of human parasites were 55.27%, 21.38% and 3.41%, respectively[96]. The infection rate of soil-transmitted nematodes across the country has been substantially reduced in

Table 4. Types, distribution and pathogenicity of foodborne protozoan infections in China.

Food category	Family or Species	Food vehicles	Distribution			Parasitic sites	Pathogenicity	Ref.
			Temporal	Spatial	Population			
Land animals	*Sarcocystis*	Beef, pork and other meats	N/A	N/A	N/A	Small intestine and muscle tissue	Asymptomatic; typical symptoms: digestive disorder; severe symptoms: anemia, necrotic enteritis, bronchospasm, hoarseness and myocarditis	[43]
Plants	*Trypanosoma*	Fruit juice or acai	N/A	N/A	Farmers	Macrophages, fibroblasts, and muscle tissue	Acute phase: chagoma, headache, fever, hepatosplenic lymphadenopathy, and meningitis symptoms; chronic phase: myocarditis, giant colon, and giant esophagus	[44]
Others	*Trichomonas hominis*	Food or water contaminated with the trophozoite	N/A	N/A	Children or people with intellectual disability and mental illness	Cecum and colon	Typical symptoms: “traveler's diarrhea”, chronic diarrhea; severe symptoms: malnutrition and growth retardation	[45]
	Giardia	Food or water contaminated with the cyst	N/A	Rural areas	Children, frail and immunodeficient individuals	Duodenum and upper small intestine	Asymptomatic; typical symptoms: acute and chronic diarrhea with rotten feces and malabsorption syndrome	[46]
	Lophomonas	Contaminated food or water	N/A	N/A	The middle-aged and elderly, and immunodeficient patients	Upper respiratory tract, lung tissue	Low fever, cough, mucus foamy sputum, and severe asthma attack	[17]
	Entamoeba histolytica, Entamoeba coli	Food or water contaminated with the cyst	N/A	Yunnan, Guizhou, Xinjiang, Gansu	Children aged less than 14 years and adults older than 40 years, men and people residing in areas with poor sanitation or immunosuppression	Colon, parenteral: liver, thorax, abdomen, pericardium, lung, brain	Intestinal amoebiasis: diarrhea and amoebic granulomas; parenteral amoebiasis: amoebic liver abscess, chest pain, chocolate sauce-like sputum, and brain abscess	[47]
	Toxoplasma	Food such as meat products, eggs and milk or water containing each stage of *Toxoplasma*	N/A	Nationwide	Fetuses, patients with tumors and immune dysfunction	Nucleated cells, often involving the brain and eyes	Congenital toxoplasmosis: adverse pregnancy outcomes; acquired toxoplasmosis: asymptomatic or low fever, headache, lymphadenopathy; severe symptoms: central nervous system damage, retinal choroiditis and even systemic toxoplasmosis	[48]
	Cryptosporidium, Isospora belli	Contaminated food or water	Higher incidence in warm and humid seasons	Rural areas, coastal ports, regions with economic backwardness and poor sanitation, and livestock areas	Infants under 2 years old, tourists, and immunodeficient patients	Intestinal mucosal epithelial cells; parenteral: respiratory tract, biliary tract	Patients with normal immunity: diarrhea and abdominal pain. Immunodeficient patients: persistent cholera-like watery diarrhea and severe abdominal pain, often with cryptosporidiosis of parenteral organs	[49, 50]
	Balantidium, Blastocystis	Food or water contaminated with the cyst	N/A	Yunnan, Guangxi, Guangdong, *etc.*	Pig breeder, immunodeficient patients, individuals with a mental disability and tropical tourists	Colon, ileocecum, extraintestinal tissue	Asymptomatic; typical symptoms: diarrhea, spastic abdominal pain; severe symptoms: mucus, pus, and blood, along with bowel perforation; acute symptoms: dysentery; chronic symptoms: periodic diarrhea	[51, 52]

Table 5. Typical cases of common foodborne parasitic diseases in China and their diagnosis and treatment.

Pathogen	Cases' source	Route of infection	Clinical features	Diagnosis and treatment	Diagnosis methods	Ref.
Gongylonema pulchrum	2020, Shandong, China	Drank raw water contaminated by cockroaches	Pain and discomfort behind the sternum	Underwent a gastroscopy	Identified the nematodes detected using gastroscopy	[53]
Dipylidium caninum	2020, Yunnan, China	Contact with a dog, fecal analysis showed worm eggs	White, noodle-like, creepy worms found in feces; elevated blood eosinophil counts	Diagnosed with "cestode infection" (untyped); albendazole was administered	Identified the submitted cestode	[54]
Rhabditis axei	2019, Shanxi, China	Contact with sewage and rotting plants	Hemiplegia of the left lower extremity and sensory disturbance of the left side	Diagnosis with "acute cerebral infarction", no special treatment for parasitic infections	Routine microscopy of the urine showed a certain number of active parasites	[55]
Trichuris trichiura	2019, Guizhou, China	Rural children	Repeated abdominal pain, syncope; fecal occult blood; gastroscopy showed chronic gastroenteritis	Suspected of abdominal pain epilepsy and chronic gastritis	A colonoscopy revealed whipworm bodies in the ileocecal area and a biopsy was taken	[56]
Echinococcus granulosus	2019, Guangdong, China	Came from the pastoral area in Sichuan, with a history of cattle and sheep contact	Mild tenderness in the right upper abdomen and under the xiphoid process; ultrasound and CT considered primary liver cancer	Diagnosed with "a malignant liver tumor with lymph node metastasis". Laparotomy and gastrojejunostomy were performed. Later, "hepatic cancer recurred" and liver biopsy was performed twice.	Cysts and dead larvae were observed in the second liver biopsy	[57]
Lophomonas blattarum	2019, Fujian, China	Contacted termites	Cough, expectoration, and high fever with chills, dizziness, fatigue, and shortness of breath after exercise; elevated white blood cell count; CT showed multiple patchy shadows in both lungs	Multiple antibiotics were administered, but the patient still had a high fever	Dead trophozoites were found in the alveolar lavage fluid	[58]
Trichostrongylus orientalis	2018, Guangxi, China	Had served in the military in Guangzhou and farmed in Guangxi	Repeated right lower back pain with intermittent hematuria; B ultrasound showed right kidney stones, right kidney hydrops and enlarged prostate	Preliminary diagnosis: Multiple stones in the right kidney with hydronephrosis; urinary tract infection; benign prostatic hyperplasia	Fecal smear microscopy revealed eggs of the hookworm *Theileria orientalis*	[59]
Blastocystis hominis	2018, Guangxi, China	Unknown	Diarrhea with bloating, nausea, vomiting, loss of appetite	Suspected of indigestion, had taken Chinese medicine but without effectiveness	Cysts found in the fecal test	[60]
Gnathostoma spinigerum	2017, Zhejiang, China	Removed 4 worms from a wild boar stomach and swallowed	Drill-like upper abdominal pain with fever	Self-administered painkillers but without effectiveness	Identified the worm detected using gastroscopy	[61]
Trichomonas hominis	2017, Sichuan, China	Contact with water in the bathing basin that was contaminated	Vomiting, diarrhea, paroxysmal lower abdominal pain	Metronidazole was administered after diagnosis	Direct microscopy, followed by iodine and Wright-Giemsa staining and microscopy	[62]
Clonorchis sinensis	2017, Hubei, China	Cysts on the surface of the fish body stained the hand when fishing, and were eaten with dry food	Yellow urine, intermittent fever with chills; impaired liver function, increased eosinophil count	Liver protection, antispasmodic and anti-infective treatments were administered, and the patient was diagnosed with "alcoholic hepatitis"	Parasite antibody detection: liver fluke (+); a large number of liver fluke eggs were detected in the feces	[63]
Fasciolopsis buski	2017, Yunnan, China	Lived in susceptible areas, and had eaten aquatic plants	Repeated right upper quadrant pain; elevated eosinophil count; MRI suggested hepatic bile duct tumors	Repeated treatment for biliary tract inflammation with poor results; subsequently diagnosed with a hepatobiliary tumor, and a laparotomy was performed.	A worm was removed from the middle of the common bile duct intraoperatively	[64]
Taenia saginata	2015, Xinjiang, China	Often grilled and ate half-roasted beef and entrails	Repeatedly ejected proglottids	Dewormed incompletely	Identified the proglottids ejected	[65]

Table 5. Continued.

Pathogen	Cases' source	Route of infection	Clinical features	Diagnosis and treatment	Diagnosis methods	Ref.
Fasciola hepatica	2013, Guizhou, China	Ate raw *Zizania aquatica*	Repeated right upper quadrant pain with diarrhea and fatigue, yellowish staining of sclera and skin and tea-like urine; impaired liver function and elevated blood eosinophil count; MRI showed secondary expansion of bile duct stones, chronic cholecystitis	Diagnosed with "obstructive jaundice, bile duct stones", and underwent laparotomy and cholecystectomy	Four live parasites were found in the common bile duct during the operation	[66]
Entamoeba histolytica	2013, Zhejiang, China	Unknown	Chest tightness, shortness of breath, wheezing, coughing with white viscous sputum	Anti-infection, antituberculosis and other treatments were not effective.	Identified the trophozoites found by fibrobronchoscopy	[67]
Paragonimus westermani	2012, Hubei, China	Ate 3 crabs in the creek	Cold-like symptoms, lumbar mass; increased eosinophil counts; CT shows inflammation of the left lower lung and effusion in the left pleura and pericardia	Diagnosed with left tuberculous pleurisy and left lower pneumonia, and antituberculosis treatment was administered	Parasite antibody detection: lung fluke (+)	[63]
Toxocara canis	2012, Jiangsu, China	Close contact with dogs	Red eyes with a small amount of white discharge, decreased vision	Diagnosed with "conjunctivitis", continuous administration of antibiotic drops did not improve the condition	Ultrasound biomicroscope examined the changes in the anterior segment; serum anti-*T. canis* IgG (+)	[68]
Diphyllobothrium latum	2012, Fujian, China	Ate raw salmon and tuna, often with mustard	Fatigue, hunger, occasional abdominal distension and abdominal discomfort, repeated excretion of worms	Self-administered *Bacillus licheniformis* capsules	Identified the worms	[69]
Toxoplasma gondii	2012, Yunnan, China	The skin was scratched by cats, and the patient had a habit of eating raw meat	Repeated chatter, abnormal behavior, lax thinking structure, emotional instability, fear, unconsciousness	Diagnosed with schizophrenia and treated with antipsychotics, but the condition recurred	Serological test: strong positive; pathogenic examination: trophozoites were identified	[70]
Spirometra mansoni	2011, Anhui, China	Frequently directly contacted, slaughtered, and ate frogs	Upper abdominal migratory mass with itching and intermittent local pain	Diagnosed with "lipoma" and underwent surgical resection	Nematodes were found inside the mass when removing it	[71]
Enterobius vermicularis	2011, Guangdong, China	Unknown	Repeated itching of the vulva, exacerbation at night, a little yellow secretion at the meatus urinarius, with urinary pain	Diagnosis with "vulvitis and urinary tract infection"; various antibiotics were administered with poor results	At night, when the child fell asleep, white rice grain-sized peristaltic nematodes were found around his anus	[72]
Anisakis	2010, Dalian, China	Had a habit of eating raw fish	Vomiting, peripheral umbilicus and abdominal distension, and frequent mucous diarrhea	After the removal of the larvae of *Anisakis*, the inflammation symptoms disappeared	Diagnosis with an electronic gastroscope	[73]
Dioctophyma renale	2008, Hainan, China	Ate raw fish, lettuce and drank contaminated water	Weakness, dull pain in the right lower back, frequent urination, hematuria and excretion of worms with urine; B ultrasound showed enlarged right kidney and multiple cord-like hyperechoic responses in the renal parenchyma	Diagnosed with "*Dioctophyma renale* infection", but no eggs were found in multiple urine tests after admission	Identified the submitted worms	[74]
Taenia asiatica	2007, Yunnan, China	The families had a history of excretion of proglottids, and ate undercooked pork and beef	Insomnia, palpitations, dizziness, fatigue, abdominal discomfort on an empty stomach, slightly swollen abdomen; excreted proglottids	Diagnosed with taeniasis suis	Fecal examination revealed proglottids	[75]
Taenia solium	2006, Beijing, China	People from Datong, Shanxi, with poor family economic conditions	Headache, vomiting, unclear vision in both eyes, blindness, and involuntary twitching of the right upper limb; elevated CSF eosinophil counts	Multiple head CT and cerebrospinal fluid examinations were performed	Blood and cerebrospinal fluid ELISA tests for cysticercus antibodies were positive	[76]

Table 5. Continued.

Pathogen	Cases' source	Route of infection	Clinical features	Diagnosis and treatment	Diagnosis methods	Ref.
Heterophyid trematodes	2006, Fujian, China	Ate sashimi in Guangzhou	Repeated cough, chest tightness, shortness of breath, fever, fatigue, pain in the liver area, digestive disorder, difficulty in pronunciation; elevated eosinophil counts, impaired liver function; B ultrasound showing multiple placeholders in the liver	Fluid infusion and oral medication were administered, and liver function improved after one week, but eosinophil counts were still high until prednisone was administered, and increased again after stopping treatment	Liver fluke antibody tests (+), and feces tests revealed eggs of *Clonorchis sinensis* and *Heterophyid trematodes*, and the patient diagnosed with a mixed infection of these parasites	[77]
Raillietina celebensis	2006, Guangxi, China	Often played on the ground	White and peristaltic proglottids were often observed in feces	Deworming treatment after diagnosis	Proglottids were found in routine fecal tests	[78]
Bertiella studeri	2006, Shanghai, China	Frequent contact with macaques, then eating without washing hands; similar proglottids were also detected in macaque feces	Abdominal pain around the umbilicus, white proglottids were discharged, usually with a strong appetite and often feeling hungry; elevated blood eosinophil counts	First, the types of cestodes were unknown and no treatment was administered; the cestode was later identified as the *Pseudanoplocephala crawfordi*	Microscopic examination of the submitted proglottids, which was identified as *Bertiella studeri*	[79]
Capillaria hepatica	2004, Henan, China	Rural toddler	Persistent high fever, enlarged liver and spleen; increased eosinophil counts in the blood	Antibacterial treatment for many days; suspected of schistosomiasis cirrhosis	Liver tissue biopsy showed clusters of immature eggs of *Capillaria hepatica*	[80]
Giardia lamblia	2004, Sichuan, China	Tibetans	Peri-umbilical pain, diarrhea, yellow, watery and malodorous feces accompanied by tenesmus; occult blood test (+)	Enrofloxacin, norfloxacin and supportive treatment were administered without improvement	Colonoscopy of intestinal mucosa biopsy showed *Giardia lamblia* cysts	[81]
Echinostomatidae	2002, Fujian, China	Caught fish and shrimp in the pond for food	Headache, dizziness, abdominal pain, diarrhea, loss of appetite	Praziquantel for deworming	Eggs were found in the fecal examination	[82]
Ascaris lumbricoides	2001, Henan, China	Farmers with poor sanitation	Melena, weight loss, fatigue with upper abdominal pain, nausea and vomiting; occult blood (+++), anemia	Diagnosed with "a gastrointestinal tumor with upper gastrointestinal bleeding", no significant improvement after hemostatic treatment	Gastroscopy revealed more than ten roundworms in the duodenum	[83]
Pseudanoplocephala crawfordi	2000, Henan, China	Stored grain pests	Abdominal pain, diarrhea, yellow loose stools, excreting proglottids with dizziness and other symptoms	Diagnosed with "enteritis" and treated with norfloxacin and furazolidone	Identified submitted proglottids	[84]
Isospora belli	2000, Guangxi, China	Liked hot pot	Fever, vomiting, and loose stool	Diagnosed with "liver fluke infection" and deworming treatment was administered	Immature oocysts were found in the fecal tests	[85]
Mammomonogamus	1998, Hainan, China	Ate raw turtle eggs, turtle blood and turtle liver	Fever, cough, sputum, hemoptysis, wheezing, and hoarseness; CT examination showed nodular shadows with burrs in the right lung	Treated with various antibiotics for "*Streptococcus pneumoniae*" and "*Mycoplasma pneumoniae*", but the condition was not improved	Eggs were found in feces, sputum, and bronchoscopy	[86]

Table 5. Continued.

Pathogen	Cases' source	Route of infection	Clinical features	Diagnosis and treatment	Diagnosis methods	Ref.
Trichinella spiralis	1998, Shanghai, China	Ate at roadside stands close to Henan Province where trichinellosis is endemic	Abdominal distension, vomiting and fever, muscle aches with hematuria, local tenderness in gastrocnemius; slightly more eosinophils in the bone marrow examination; blood RF and anti-RNP antibodies were positive; muscle electrogram suggested a high potential for myogenic changes	Diagnosed with "mixed connective tissue disease" and "rheumatoid arthritis", hydrocortisone was administered, high fever transitioned to moderate fever, but no improvement was observed in myalgia and hematuria	Weakly positive circulating antibodies were detected in a serological examination, symptoms disappeared after the administration of albendazole	[87]
Dracunculus medinensis	1995, Anhui, China	Often drank untreated pond water, and swam in ponds	A subcutaneous mass in the left abdomen, with the size of a ping-pong ball, and felt a little pain and discomfort when touched	Resection under local anesthesia	Removed a white worm from the pus cavity and identified it	[88]
Angiostrongylus cantonensis	1995, Guangdong, China	*Angiostrongylus cantonensis* was found in rodents near the residence	Fever, paleness, shortness of breath, and blurred consciousness; elevated blood eosinophil counts, white blood cell counts and protein levels in the cerebrospinal fluid; chest radiograph showing bronchitis	Diagnosed with "purulent or tuberculous meningitis", and "pneumonia" and died due to respiratory failure	Autopsy revealed worms in pulmonary and cerebral arteries	[89]
Echinococcus multilocularis	1994, Qinghai, China	Herdsmen of Qinghai, and contacted cattle and sheep	Abdominal pain and discomfort, with poor appetite, nausea, masses under the xiphoid that were hard to the touch; B ultrasounds suggested "liver cancer"	Treated for gastric ulcers and underwent abdominal exploration	Pathological examination of the mass revealed the cystic wall and the alveolar hydatid cyst	[90]
Hymenolepis nana	1994, Hebei, China	Unknown	Abdominal pain below the umbilicus, and occasional pus and blood in the stool	Unknown	Eggs of *Hymenolepis nana* were found in the feces	[91]
Cryptosporidium	1991, Henan, China	Unknown	Watery diarrhea, anorexia, vomiting, fever and Irritable	Diagnosed with "enteritis" or "indigestion"	*Cryptosporidium* oocysts were observed in diarrhea stool	[92]
Dientamoeba fragilis	1987, Hebei, China	Unknown	Chronic diarrhea, thin stools with mucus, loss of appetite, and fatigue; colonoscopy showed colitis	Diagnosis with "chronic colitis"	A direct smear test of the stool revealed trophozoites	[93]
Staphylococcus hominis	1986, Yunnan, China	Ate raw pig skin	Intermittent umbilical or epigastric pain, thin stools	Detected in an epidemiological survey	Spores and oocysts were found in stools	[94]
Balantidium coli	1981, Zhejiang, China	Frequently exposed to pig feces containing cysts	Abdominal pain, diarrhea, slime with mucus in the stool, and occasional colic	Treatment (specific unknown) for two months without effectiveness	A large number of trophozoites were found in a routine fecal examination	[95]

recent years[96], which is closely related to the social and economic development and the adoption of scientific prevention measures in China. However, the prevalence of food-transmitted parasitic diseases such as trichinellosis, clonorchiasis, paragonimiasis, cysticercosis, and echinococcosis has increased significantly[97]. The third survey of parasitic infections in China showed that the leading causes of foodborne parasitic disease (infection rate) in China were *Ascaris lumbricoides* (1.36%), followed by *Trichuris trichiura* (1.02%) and *Clonorchis sinensis* (0.23%). The overall infection rates of intestinal protozoa and cestodes were 0.99% and 0.06%, respectively[96]. The fastest-growing foodborne parasitic diseases in China included clonorchiasis, angiostrongyliasis, echinococcosis, trichinellosis and cysticercosis[97]. In recent years, some new changes in the prevalence of foodborne parasitic diseases in China have occurred, which merit attention.

4.1.1. Eating habits change due to intra- and intercountry dietary culture exchanges

China has 56 ethnic groups and 34 provinces (autonomous regions, municipalities and special administrative regions). Each region has its own unique food culture, leading to the prevalence of different types of foodborne parasitic diseases. For example, in Shunde, Guangdong, local people like to eat sashimi, and a survey conducted in 2014-2015 showed that the infection rate of *Clonorchis sinensis* among local residents was up to 42.38%[98]. In Tibet, nomads have more contact with sheep, dogs, and wolves, and thus their food is more likely to be contaminated with the eggs of *Echinococcus*. Inspections conducted from 2012 to 2016 estimated that the prevalence of echinococcosis in the Tibetan population was 1.66%[99]. People in Yunnan have the habit of eating raw or half-raw pork. Since 2000, 21 outbreaks of human trichinosis have been reported in Yunnan Province, with 2 256 cases and 3 deaths[100]. Freshwater snails are widely distributed in Hainan Province, and locals have the habit of eating *Ampullaria gigas*. An epidemiological survey conducted in Hainan Province indicated that the positive rate of *Angiostrongylus cantonensis* IgG antibody in the serum was 20.3%[101].

In recent years, with the rapid development of tourism and the catering industry, food culture exchanges between various regions have increased rapidly, thus these so-called local diseases are no longer confined to the previous epidemic areas in China, which might lead to sporadic cases or even outbreaks. For example, Hubei and Henan reported cases of trichinosis caused by eating undercooked pork[102]. From June to September 2006, a hospital in Beijing treated 141 patients with angiostrongyliasis, all of whom dined at a restaurant in Beijing. They all ate uncooked *Ampullaria gigas* from Guilin, Guangxi[103].

Second, with the increase in economic globalization, an increasing amount of foreign food appears on the Chinese table. If these foods are not properly processed, they are likely to carry some parasites that are not available in China or have been controlled, causing the spread or even outbreaks of new or recurring foodborne parasitic diseases. For example, in June 1998, an outbreak of imported paragonimiasis occurred in Dandong City, Liaoning Province. Among the 676 people who consumed imported river crabs, 623 had the disease, with an incidence rate of 92.2%[104]. In 1994, the Ruili Animal and Plant Quarantine Bureau of Yunnan found 12 *Anisakis* larvae in imported hairtails from the Bay of Bengal[105]. Currently, an increasing number of Chinese people are gradually accepting Japanese sushi or sashimi, which might lead to *Anisakis* infection[106].

4.1.2. Increased risk of acquiring foodborne parasitic zoonotic diseases

Most foodborne parasitic diseases are zoonotic diseases, such as echinococcosis, trichinosis and toxoplasmosis. As the economy develops, keeping a pet is becoming a new hobby of the new generation[107], and thus the number of people keeping pets obviously increases, which leads to increased contact with animals, and the infective stages of parasites from these animals might contaminate the food, thereby resulting in infection. For example, an epidemiological survey of cat toxoplasmosis conducted in Beijing showed that the apparent prevalence rate was 2.0% in 2014 and increased to 7.2% in 2015[108]. Another survey carried out in areas including Heilongjiang, Jilin, Liaoning and Inner Mongolia, where residents form a habit of breeding dogs and cats, revealed a high overall parasitic infection rate in animal fecal and serum samples (20.77%), and many common foodborne parasites were detected, such as *Toxocara canis* (28.23% in dogs) and *Toxocara cati* (5.29% in cats)[109].

4.1.3. Urbanization causes increases in population inflow and the risk of foodborne parasitic diseases

The current parasitic infection rate in rural areas is higher than that in urban areas in China[96]. However, as the process of urbanization accelerates, an increasing number of rural populations enter cities, which may cause an increase in the infection rate of foodborne parasites in cities. For example, in the past, paragonimiasis was presumed to occur in areas with poor sanitation conditions in Jiangsu, Zhejiang, Guangdong and Guangxi and rarely in cities. However, in recent years, paragonimiasis has continued to appear in cities, and the incidence is increasing annually, even showing outbreaks in families. Due to the particularity of the disease, it was called "urban paragonimiasis"[110].

4.2. Prevention and control strategies for foodborne parasitic diseases in China

Due to the diseases themselves (mild or nonspecific symptoms and diverse clinical symptoms), low public awareness, neglect of medical personnel and lack of sensitive and specific detection methods[4], misdiagnosis and missed diagnosis of foodborne parasitic diseases in the clinic occur frequently, further aggravating their harmfulness and people in the rural regions were more infected than those living in the urban areas[111]. As shown in Table 5, eating raw fish or meat accounted for 32.6% of the observed infection routes, drinking raw water or eating plants accounted

for 13.9%, contacting animals accounts for 18.6%, and others and unknown account for 34.9%. Among all cases reported in China, many researchers have overlooked the importance of investigating the route of infection, and mostly only cases characterized by severe or chronic symptoms would be published, which may not represent the most common cases.

The basic principle of infectious disease control is to manage the three links of parasitic disease epidemics, namely, the source of infection, transmission route and susceptible people[17]. In addition to increasing awareness of prevention, strengthening health education, reinforcing the vigilance of medical staff, and comprehensively applying laboratory inspection methods[4], food hygiene inspections and supervision are important. The eating habits and customs of humans are difficult to change, but further improvements in food safety could solve this problem, such as the development of a *Bacillus subtilis*-based fish vaccine against *Clonorchis sinensis* infection[112]. In addition, efforts to restrict the contamination of food with infective stages is another solution. For instance, the detection of parasite infections in pets, livestock and wild animals should be strengthened. We can also control the source of infection by controlling the animal host. For example, if dogs were prevented from eating raw offal or were wormed, the control of *Echinococcus granulosus* might improve.

In addition, the prevention and control of foodborne parasitic diseases is a global issue. In countries around China, the problem of parasites remains severe[113]. In the mainstream of globalization, we cannot preserve our dignity as a nobody. Therefore, we should pay attention to the prevalence of parasitic diseases in the countries around China and provide them with assistance to reduce the burden of foodborne parasitic diseases.

The limitations of this article are listed below. 1) The included literature was limited to studies published in English and Chinese, and the gray literature was not searched, which may lead to the loss of data from some areas in studies written in the local language or that has not been formally published. 2) Reports and research on parasitic infections and foodborne parasitic diseases are constantly being updated, and the cases and epidemiological data in this article have temporal validity.

With the progress of economic globalization and food diversification, foodborne parasites are becoming increasingly common in both developing and developed countries, endangering human health and imposing great challenges in public health, including China. From the current situation presented above, we concluded that the diverse eating habits, closely contact with animals, and urbanization are increasing the risk of foodborne parasitic diseases in China. Although effective drugs are available for many foodborne parasitic diseases, they remain an important public health issue that merits further attention, and the emphasis should be placed on raising the awareness of prevention, strengthening health education and food hygiene inspections, reinforcing the vigilance of medical staff, and comprehensively applying laboratory inspection methods for their prevention and control.

Conflict of interest statement

We declare that we have no conflict of interest.

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Authors' contributions

LS and QX were responsible for study selection and data extraction and drafted the manuscript. LS and ZL designed the study and revised the manuscript. All authors read and approved the final manuscript.

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